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# मानक

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IS 10235-2 (1982): Glossary of terms in orthopaedics, Part 2: Mechanics and materials for implants [MHD 2: Orthopaedic Instruments, Implants and Accessories]



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Bhartrhari—Nitiśatakam

“Knowledge is such a treasure which cannot be stolen”



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IS : 10235 ( Part II ) - 1982

*Indian Standard* Reaffirmed 1989

## GLOSSARY OF TERMS IN ORTHOPAEDICS

### PART II MECHANICS AND MATERIALS FOR IMPLANTS

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**INDIAN STANDARDS INSTITUTION**  
MANAK BHAVAN, 9 BAHADUR SHAH ZAFAR MARG  
NEW DELHI 110002

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# Indian Standard

## GLOSSARY OF TERMS IN ORTHOPAEDICS

### PART II MECHANICS AND MATERIALS FOR IMPLANTS

Orthopaedic Instruments and Accessories Sectional  
Committee, CPDC 24

*Chairman*

DR K. S. MASALAWALA  
Bombay Mutual Terrace Building  
534, Sandhurst Bridge  
Bombay

*Members*

SHRI S. C. BHATTACHARYA

SHRI P. R. T. THULASINGAM ( *Alternate* )

COL A. S. CHAHAL

LT-COL D. J. MOOKHERJEE ( *Alternate* )

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SHRI R. D. GUPTA

SHRI B. M. KAUSHIK

SMT VIMAL PITRE

SHRI V. R. GORE ( *Alternate* )

SHRI A. L. SAIGAL

SHRI ASHOK KUMAR ( *Alternate* )

DR T. K. SHANMUGASUNDARAM

DR R. P. SINGH

SHRI R. N. VIG

DR A. S. SETHI,

Director ( Consr Prods & Med Instrs )

*Representing*

Indian Drugs & Pharmaceutical Limited, New  
Delhi

Ministry of Defence ( DGAFMS )

Delhi Administration, New Delhi

Department of Health & Family Welfare, Govern-  
ment of West Bengal, Calcutta

Ministry of Defence ( DGI )

Punjab Surgical Instruments Manufacturers &  
Suppliers Association, Jullundur

National Metallurgical Laboratory ( CSIR ),  
Jamshedpur

Vikas Orthopaedic Corporation, New Delhi

Sushrut Surgicals Pvt Ltd, Bombay

The Metropolitan Surgical Works, Delhi

Health & Family Welfare Department, Govern-  
ment of Tamil Nadu, Madras

Directorate of Health Services, Government of  
Bihar, Patna

Imperial Surgical Co Pvt Ltd, Bombay

Director General, ISI ( *Ex-officio Member* )

*Secretary*

SHRI D. K. AGRAWAL

Deputy Director ( Consr Prods & Med Instrs ), ISI

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## *Indian Standard*

### GLOSSARY OF TERMS IN ORTHOPAEDICS

#### PART II MECHANICS AND MATERIALS FOR IMPLANTS

##### 0. FOREWORD

**0.1** This Indian Standard was adopted by the Indian Standards Institution on 17 May 1982, after the draft finalized by the Orthopaedic Instruments and Accessories Sectional Committee had been approved by the Consumer Products and Medical Instruments Division Council.

**0.2** The definition of an item is very important as it provides information on its technical aspects. Uniformity in definition will also eliminate different interpretations and disputes.

**0.3** This Indian Standard is based on ISO/DP 6017/II-2 — 'Implants for surgery — Terminology Part II — Mechanics and materials for implants', issued by the International Organization for Standardization ( ISO ).

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##### 1. SCOPE

**1.1** This standard specifies definitions relating to terms in mechanics and materials relevant to surgical implants.

##### 2. TERMINOLOGY

###### 2.1 Basic Mechanical Terms:

<i>Term</i>	<i>Definition</i>
Force	Force is that which tends to accelerate a body. In the living human body the forces are generally developed by muscles and will relate to the external effects of gravity and the accelerations which the human body undergoes ( N ).
Resultant force	Where a system of forces acts on a body or part of a body, their total effect can be represented by a single resultant force or a couple.
Mass	Quantity of matter in a body ( kg ).
Weight	Gravitational force exerted on a body ( N ).

*Term**Definition*

Load	Any action applied to a body which may cause deformation or fracture — especially force and moment.
Free body diagram	When the loading on a body component is analysed, a single part or any group of parts may be studied and the equations of equilibrium must be satisfied for each part or group of parts. Attention must be paid to all the loads transmitted to them by the external environment and by the remainder of the body at the section joining this part or group of parts to the rest of the body. The illustration of such a system is called a free body diagram.
Pressure	Where a force $F$ is uniformly distributed over a surface area $A$ of a body the pressure is given by $F/A$ ( pa, N/mm <sup>2</sup> ).
Moment	Turning effect of a force about an axis is given by the product of the force $F$ and the distance $h$ measured perpendicularly from the axis to the line of action of the force ( Nm ).
Torque	Moment about the long axis of a body tending to produce twisting ( torsion ) (Nm).
Bending moment	Moment acting about an axis perpendicular to the long axis of a body; generally producing lateral deflection (Nm).
Couple	Moment produced by two equal forces having parallel lines of action. The value of the couple is $F \times h$ where $F$ is the value of each force and $h$ the distance between their lines of action (Nm).
Cross-sectional area	When the section is taken perpendicular to the longitudinal axis of the body, the area exposed by the cut is termed the cross-sectional area (m <sup>2</sup> ).
Centroid	The centroid of an area is its effective geometric centre. If a thin sheet is cut into the shape of an area it will balance in any position only when supported on an axis passing through the centroid.

<i>Term</i>	<i>Definition</i>
Second moment of area	Property of a section related to its area and the distribution of the area relative to its centroid — not to be confused with mass moment inertia Used in the calculation of stresses due to bending in the elastic region ( $m^4$ ).
Polar moment of area	Used in the calculation of shear stresses due to torsion of a circular section ( $m^4$ ).
Normal force	Force whose line of action coincides with the line joining the centroids of successive cross sections of a part of a body.
Tensile force EXTENSIONAL FORCE	Normal force tending to increase the length of a part of a body.
Compressive force	Normal force tending to produce shortening of the length of a part of a body.
Shear force TANGENTIAL FORCE	That component of the resultant force acting on one side of a section of a body having a line of action perpendicular to the axis of that body.
Work	Work is done when movement occurs at the point of application of a force to a body. The amount of work is given by the product of the force and the distance moved by the point of application along the line of action of the force (J) ( 1 kWh = $3.6 \times 10^6$ J ).
Energy	Capacity for doing work. In mechanical systems this will be in the form of potential energy ( relating to the possibility of work being done by gravity ); kinetic energy ( corresponding to the instantaneous linear and/or angular velocity of the body ); or strain energy corresponding to the energy stored and available for release in a deformed body ( J ).
Power	Rate of doing work or supplying energy (W).
Instantaneous centre	If two bodies A and B are so connected that relative angular movement between them is possible, then, for a particular configuration there exists an axis such that small angular movements from this position may be taken to be pure rotations about an axis through a point C.



*Term**Definition*

C is the instantaneous centre of B relative to A and of A relative to B. Generally, as finite rotations occur between A and B the instantaneous centre will trace a curve which may be drawn relative to either A or B.

**Fluid** Substance which flows. It differs from a solid in that it can offer no permanent resistance to change of shape.

**Gas** State of matter in which molecules move freely, thereby causing matter to expand indefinitely occupying the total volume of any vessel in which it is contained.

**Liquid** State of matter in which the shape of a given mass depends on the containing vessel, but the volume is independent thereof. A liquid may frequently be assumed to be incompressible.

**Turbulent flow** Fluid flow in which the particle motion at any point varies rapidly in magnitude and direction. Gives rise to high drag in the boundary layer.

**Laminar flow**  
**STREAMLINE**  
**FLOW** Fluid flow in which adjacent layers do not mix, except on a molecular scale.

## 2.2 Mechanics of Materials

**Stress** Stress at a point in the cross-section of a body is defined as the resultant of all forces acting on the body to one side of the section divided by the cross-sectional area. Loads in the material at the cross-section are transmitted by appropriate inter-molecular forces (  $\text{MPa} = \text{MN/m}^2 = \text{N/mm}^2$  ).

Generally a uniform distribution of stress exists only in the case of tensile or compressive forces whose line of action intersects the centroid.

**Normal stress**  
**DIRECT**  
**STRESS** If the line of action of the resultant force is perpendicular to the cross-section the stress is defined as normal.

**Tensile stress** Normal stress tending to increase the length of a body.

<i>Term</i>	<i>Definition</i>
Compressive stress	Normal stress tending to decrease the length of a body.
Shear stress TANGENTIAL STRESS	If the line of action of the resultant force at a section of a member is parallel to the cross section, the stress is defined as shear or tangential stress.
Bending stresses	Tensile and compressive stresses developed on opposite sides of a body due to the application of a bending moment.
Shear stress due to torsion TORSION STRESS	Shear stresses produced in a body on the application of a torque.
Resultant stress	Where several load systems act on a body the stresses at a point due to each load can be combined by appropriate analysis to give a single resultant stress system.
Stress raiser	Scratch, crack, notch, void, inclusion change in cross section or change in contour causing stress concentration.
Stress concentration	Increased value of stress existing in the region of a stress raiser compared with that occurring in a similarly loaded uniform body.
Stress concentration factor	Ratio of the stress at a stress concentration to the value occurring at the corresponding point in a uniform body subject to the same loading.
Thermal stress	Stress developed within a body when free thermal expansion or contraction is restrained or the distribution of temperature throughout a body is non-uniform.
Residual stress	Stress remaining in a body after removal of any system of external loads or temperature gradient.
Deformation	Change in dimensions or shape of a body.
Strain	Ratio of the deformation of a body or part of a body to its original dimensions.
Normal strain	Ratio of the change of length of a member to its original length. Normal strain may be tensile or compressive.

## Term

## Definition

Shear strain  
TANGENTIAL  
STRAIN

Where an element of a body of shape ABDC deforms as shown in Fig 1 the shear strain is defined as angle  $G$  ( radians ).

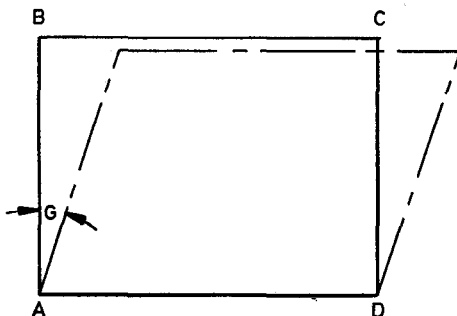


FIG. 1. SHEAR STRAIN DIAGRAM

Volumetric strain	Ratio of change in volume to original volume.
Strain gauge	Device affixed usually to the surface of a body to measure the average normal strain in a specified direction over the area of attachment.
Stress/strain curve	For any material there is generally a continuous relationship between stress and strain, for example as shown in Fig. 2.
Elastic deformation	Deformation due to load which diminishes to zero on removal of that load.
Plastic deformation PERMANENT DEFORMATION	Deformation due to load which does not come to zero on removal of that load.
Visco-elastic deformation	Deformation which comprises elastic, plastic and fluid flow components.
Elastic modulus	Ratio of stress to corresponding strain within the initial linear region of the stress/strain curve for a material.
Young's modulus	Elastic modulus relating normal stress to strain.
Shear modulus RIGIDITY MODULUS	Elastic modulus relating shear stress to shear strain.

Term	Definition
Bulk modulus	Elastic modulus relating volumetric stresses to volumetric strain.
Poisson's ratio ( $\nu$ )	Ratio of lateral strain to longitudinal strain in a body loaded by a tensile force only ( see Fig. 3 ).

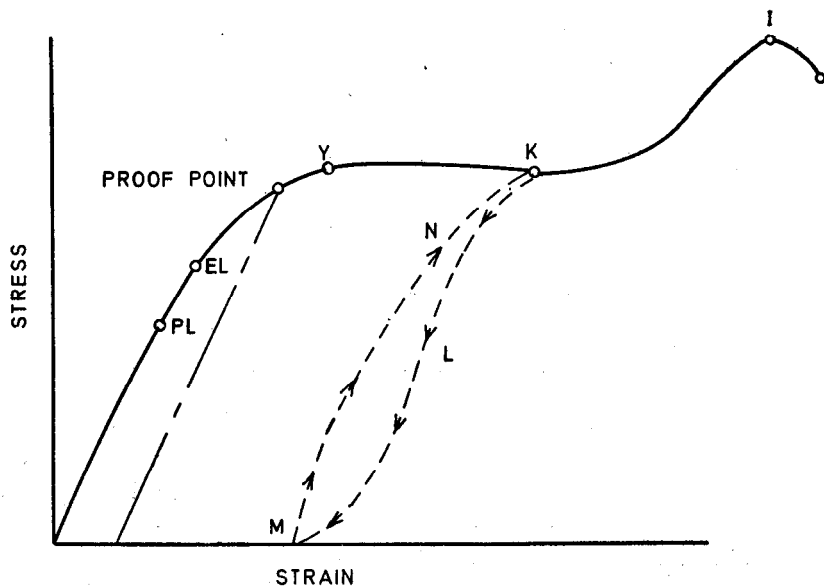
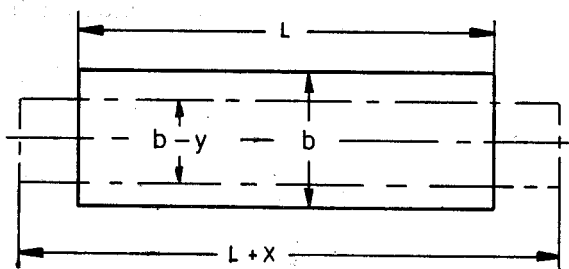


FIG. 2. TYPICAL STRESS/STRAIN CURVE



$L$  = Original length,                       $x$  = Elongation, and  
 $b$  = Original thickness,                   $y$  = Contraction  
 Lateral strain =  $\frac{y}{b}$   
 Longitudinal strain =  $\frac{x}{L}$   
 Poisson's ratio =  $\frac{\frac{y}{b}}{\frac{x}{L}} = \frac{yL}{bx}$

FIG. 3 DIAGRAM ILLUSTRATING POISSON'S RATIO

<i>Term</i>	<i>Definition</i>
Load elongation curve	In a tensile test of a standard test piece simultaneous measurements are made of the axis load $F$ and the elongation $X$ on a specified gauge length. The graph of $F$ to $X$ is the load/elongation curve with appropriate change of scale. This may be used as a stress/strain curve.
Proportional limit	Point in a stress/strain curve at which there is significant deviation from the initial linear region ( <i>see</i> point $PL$ in Fig. 2 ).
Proportional limit stress	Stress at the proportional limit.
Elastic limit	Point in a stress/strain curve at which the material ceases to behave in an elastic manner ( <i>see</i> point $EL$ of Fig. 2 ).
Elastic limit stress	Stress at the elastic limit.
Proof stress	The stress in a material corresponding to a permanent strain of a prescribed amount, for example, 0.1 %.
Yield	That part of the stress/strain curve which is essentially parallel to the strain axis.
Yield stress	Load at yield divided by the original cross-sectional area.
Ultimate tensile stress	Maximum load in a tensile test divided by the original cross-sectional area.
True stress	At any stage in a tensile test the true stress is the load divided by the actual cross-sectional area at that stage.
Hysteresis	Phenomenon whereby the loading curve differs from the unloading curve for any point in a stress/strain diagram. In Fig. 2, if the test is conducted up to point $K$ and unloading takes place along line $KLM$ , the typical curve representing reloading follows path $MNK$ . The area $KLMN$ represents mechanical energy loss.
Creep	Continuous deformation of a material when subjected to stress over an extended period. Generally, the higher the stress and the temperature, the higher will be the rate of deformation. A typical creep curve is shown in Fig. 4.

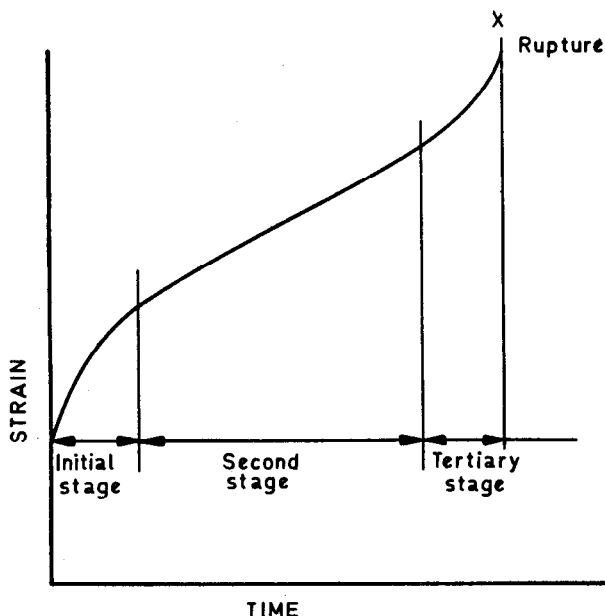


FIG. 4 TYPICAL CREEP CURVE

<i>Term</i>	<i>Definition</i>
Creep limit CREEP STRENGTH	Highest stress at a given temperature which a material can withstand without excessive deformation.
Creep rate	Rate of strain corresponding to particular load and temperature conditions as given by the slope of the second stage of the creep curve shown in Fig. 4.
Ductility	Ductility is the capacity of a material to undergo permanent ( plastic ) deformation. In a ductile fracture a cup and cone shape or 'ears' together with a fine textured surface appearance corresponding to large amounts of local deformation is frequently evident.

<i>Term</i>	<i>Definition</i>
Brittleness	Showing no significant deformation before fracture. Some materials may exhibit a transition from ductile to brittle behaviour, depending on the temperature, the speed of application of load and the stress distribution. In a brittle fracture there is no significant reduction in area and the surface may have a bright crystalline appearance.
Gauge length	A length within the uniform diameter portion of a test specimen on which deformation measurements will be made (m).
Extensometer	An instrument for measuring the average extension on the gauge length of a tensile test specimen.
Compression test	A compression test is conducted generally on a short specimen of cylindrical form ( maximum length/diameter ratio 20 ). The load is uniformly applied to the end faces.
Reduction in area	Reduction of cross-sectional area of a tensile test piece measured after fracture and expressed as a percentage of original cross-sectional area.
Elongation	Increase in gauge length of a tensile test piece measured after fracture and expressed as a percentage of the original gauge length. Generally this value is accepted only if the fracture has occurred within the middle third of the gauge length.
Ultimate shear stress	The maximum stress occurring during a test in pure shear. This can only be obtained accurately from a torsional test on a thin tube ( $MP_s = MN/m^2 = N/mm^2$ ).
Fatigue failure	Failure of a test piece or component under repeated cycles of load, each less than its ultimate load is referred to as fatigue.
S/N curve	Graph of stress to the number of load cycles to failure is known as the S/N curve.
Fatigue limit ENDURANCE LIMIT	Highest stress which will not cause failure regardless of the number of load cycles. This limit is only found in ferrous metals in non-corrosive environments ( $MP_a = MN/m^2 = N/mm^2$ ).

<i>Term</i>	<i>Definition</i>
Corrosion fatigue	Failure due to repeated cycles of load in a corrosive environment. Generally, in a corrosive environment, the number of load cycles to failure at a given stress is recorded.
Impact test	Test in which a bar is dynamically loaded to fracture. Generally, the bar is loaded in bending and notched at the region of maximum stress. Measurement is made of the minimum energy required to fracture the bar. This energy cannot be directly related to other mechanical properties.
Notch sensitivity	Reduction of the strength of certain materials in the presence of stress raisers.
Toughness	Characteristics of a material requiring high energy to fracture.
Hardness	Capacity of a material to resist indentation. It may correlate with wear resistance and yield stress.
Hardness testing	Usually determined by the use of an indentation type of machine such as Vickers ( diamond pyramid hardness ) ( HV ), Brinell ( HB ) or Rockwell ( HR ). In each case a dimensionless number is obtained which must be reported relative to the test conditions, for example, Vickers ( at stated load ), Brinell ( at stated $P/D^2$ value ), Rockwell ( using stated scale ).
Photoelasticity	<p>Phenomenon in which the transmission of light through certain transparent materials is dependent on local strain. In suitable cases using plane polarized light with calibrated materials the stress at a point in a model can be inferred from the optical fringe patterns produced.</p> <p>If a thin photoelastic coating ( stress coat ) is applied to a component, an analysis of the fringes allows the determination of the surface strain when the component is loaded. Numerical method of analysis of the stress finite element stress analysis wear in a component obtained by dividing it into a finite number of small elements. Using this technique the behaviour of a complicated two or three</p>



<i>Term</i>	<i>Definition</i>
	dimensional component can be predicted under any assumed system of loads. Removal or transfer of material from contacting surfaces due to their relative movement under load. Wear may be measured by mass change, volume measurement or by the depth of the wear tracks.
Friction coefficient	Ratio between the tangential friction force and the normal force between two surfaces when relative movement is occurring or about to commence.
Lubrication	Interposition between two surfaces of solid liquid or gaseous material to reduce the friction or wear occurring on relative movement.
Fretting	Wear occurring between two close fitting surfaces corresponding to repeated small relative movements.

### 2.3 Metals — General

Metal	Material usually possessing the properties of electrical and thermal conductivity, opacity, lustre, hardness, ductility, malleability, high melting and boiling points.
Alloy	Any metal other than a pure metallic element. Metal prepared by adding other metals or non-metals to a basic metal to secure desirable properties.
Alloying element	Element deliberately added for the purpose of modifying the properties of a metal.
Alloying	Addition of one or more elements to a metallic product to form an alloy.
Inclusions	Particles of impurities contained by a material.
Phase	Region in a material differing from another in composition or structure, or both.
Phase diagram	Diagram showing phases present in a material, their compositions and their relative amounts as functions of temperature, pressure and overall composition. When each phase is at equilibrium with its surroundings the diagram is known as an equilibrium diagram.
Matrix	Major structural constituent of a material, that is enveloping phase in which another phase is embedded.

<i>Term</i>	<i>Definition</i>
Eutectic	That mixture of two or more constituents which has the lowest freezing and melting points.
Eutectic point	Point in the equilibrium diagram indicating the composition of the eutectic and its freezing temperature.
Eutectic structure	Structure, frequently lamellar, produced by the simultaneous solidification of the components of the eutectic.
Eutectoid	That mixture of two or more constituents which forms on cooling from a solid solution and transforms on heating at a constant minimum temperature.
Eutectoid point	Point in the equilibrium diagram indicating the composition of the eutectoid and its temperature of transformation.
Eutectoid structure	Structure, frequently lamellar, produced by the simultaneous precipitation of the components of the eutectoid from the solid solution.
Eutectoid steel	Steel which consists entirely of eutectoid. In the iron/carbon system, the eutectoid occurs at approximately 0.9 % carbon and, after cooling at a suitable rate, consists entirely of pearlite.
Transformation range	Temperature range over which a significant change in phase structure occurs.
Grain	Crystalline structure of a metal; the individual crystals in a polycrystalline material.
Grain boundary	Crystal boundary; transition zone between crystalline alignments in two adjacent grains.
Grain growth	Coarsening of crystal structure (increase in grain size ) under certain conditions of heating.
Grain refining	Decreasing of grain size brought about by heating above the transformation range ( recrystallization temperature ), followed by cooling at a suitable rate. The temperature is related to the time of heating and to the prior cold-work the sample has received. Hot working and cold working, followed by annealing, are used for grain refining.

<i>Term</i>	<i>Definition</i>
Recrystallization temperature	Temperature at which recrystallization takes place to more stable strain-free crystal form. Characterized by softening. The heat treatment process is called annealing.
Ferrite ALPHA IRON — IRON	Crystal structure of pure iron stable at room temperature having a body-centred cubic crystal lattice. Soft ductile. Solubility of carbon is very low in ferrite (below 0.02%). Carbon steels up to 0.8% carbon have ferrite as matrix phase; slow cooling from austenitic produces pearlite.
Ferrite DELTA RITE	FER- Crystal form of pure iron stable above 1 390°C, having a body-centred cubic lattice. Alloying with certain elements (for example, chromium) can modify the temperature range of stability of delta ferrite which can, under some circumstances, persist to normal ambient temperature and below.
Austenite GAMMA IRON γ - IRON	Crystallographic state of iron in which the unit cell has a face-centred cubic form. This state in pure iron is stable between 910°C and 1 390°C. The range of stability can be changed markedly by alloying and in austenitic stainless steel stability is maintained at normal ambient temperature.
Iron carbide CEMENTITE	Second phase formed when carbon is present in excess of solubility limits. Orthorhombic lattice with 3 : 1 iron to carbon ratio ( $\text{Fe}_3\text{C}$ ).
Pearlite	A mixture of two phases formed by transforming austenite of eutectoid composition to ferrite and carbide by heat treatment. Microscopically a lamellar structure. Transformation begins at grain boundaries.  Carbon steels having 0.02% to 0.8% carbon shown a ferrite matrix with carbide ( $\text{Fe}_3\text{C}$ ) in lamellar structure but between 0.8% and 2.0% the matrix is carbide.
Bainite	Formed when austenite is quenched to a temperature between 200°C and 400°C.

<i>Term</i>	<i>Definition</i>
Martensite	Formed when austenite is quenched below the temperature for bainite formation. The face centred lattice changes to a body centred lattice but since the carbon remains in solution it is a tetragonal structure rather than cubic. Harder than pearlite. With sufficient time, transformation to ferrite plus carbide occurs at low temperatures, but not to a pearlite structure.
Dendrite	( <i>Adj.</i> dendritic. ) Crystal with a fir tree structure, formed by the initial freezing from a nucleus of primary branches followed by the formation of secondary branches from these at intervals forming a crystal skeleton.
Stainless steel	Corrosion resisting alloy steel containing substantial quantities of chromium, usually with nickel and other elements.
Austenitic stainless steel	Stainless steel in which the crystalline structure substantially one phase austenite.
<b>2.4 Metals — Technology and Processing</b>	
Quenching	( <i>Adj.</i> quenched. ) Process of rapid cooling to prevent formation of equilibrium crystal forms. Carried out over any temperature range to achieve desired structure.
Normalizing	Process of slow cooling to produce the low temperature equilibrium forms of ferrite and carbide. Diffusion-controlled process and thus extent of equilibrium is time-dependent.
Solution treatment SOLUTIONI- ZING	Process of putting minor components into solid solution by holding the alloy at a suitable temperature, usually just below eutectic temperature.
Precipitation hardening	Process by which alloy is solution treated, then quenched to retain the solid solution followed by heating to a suitable temperature to nucleate precipitation of the minor component which has lower solubility at the reduced temperature. Resultant strain in the matrix produces hardening and increased strength.

*Term**Definition*

Stress relief annealing	Process of heating to temperatures just below the eutectoid to relieve stresses.
Annealing	Process of heat treatment comprising heating above recrystallization temperature and cooling at controlled rate to produce recrystallization and softening. For steel, heating is into the austenite range.
Transformation hardening	Achieved by cooling from above the critical range at a rate that prevents the formation of ferrite and pearlite and results in the formation of martensite. Cooling may be in water, oil or air.
Cold-work	Deformation occurring below recrystallization temperature. Metals become harder and less ductile (strain hardening) with additional mechanical working. Hardening results from deformation of crystal and entanglements of imperfections ( dislocations ) in the crystalline lattices.
Strain hardening	Hardening caused by deformation at some temperature below the recrystallization temperature and usually at ambient temperature.
Hot-work	Deformation occurring above recrystallization temperature. Hardening does not occur since recrystallization accompanies the deformation.
Forging	Process of hammering or pressing between dies. Also used as a noun to denote the product of a forging process.
Extrusion	Process of forcing through a die, for example, to form cylindrical pipes.
Sintering	Process of heating powder at temperature below melting point under pressure so that solid state diffusion occurs between particles to produce inter-particle bonding.
Welding	Joining operation involving the melting of the joined metals at the interface between them.
Weld decay	Intercrystalline corrosion of an austenitic stainless steel in the neighbourhood of a weld, the susceptibility having been caused by the welding heat.

<i>Term</i>	<i>Definition</i>
Weld decay test	Test to determine the susceptibility of the steel to weld decay.
Casting	Means of producing a component by allowing molten metal to solidify in a mould.
Investment casting	Process of forming metal by casting molten alloy into a mould produced by the use of an expendable pattern.

## 2.5 Metals — Corrosion

Corrosion	Progressive electro-chemical action on a metal promoting destruction.
Corrosion resistance	Ability of metal to withstand electro-chemical attack under specified environmental conditions.
Intergranular corrosion INTERCRYSTALLINE CORROSION, GRAIN BOUNDARY CORROSION	Corrosion which occurs along grain boundaries between adjacent grains resulting from differences in electropotential between atoms in the boundaries and in the grains. Susceptibility to attack at the grain boundaries is associated with the formation of chromium-rich carbides which denude the adjacent zones of chromium.
Fretting corrosion	Simultaneous action of the processes of fretting and corrosion.
Stress corrosion	Enhancement of the effect of a corrosive environment on a metallic component by stress.
Stress corrosion cracking	Brittle or quasi-brittle rupture of a material under the joint action of static stress and corrosive attack, neither of which would have caused cracking while acting alone.
Corrosion fatigue	Simultaneous action of fatigue (resulting from cyclic loading) enhancing corrosion.
Sensitization ( of steel )	Condition of stainless steel resulting from incorrect heat treatment which renders it susceptible to intergranular corrosion and caused by an excess of carbide in the grain boundary.

<i>Term</i>	<i>Definition</i>
De-sensitization	Process of reducing the sensitization of austenitic stainless steel by heat treatment either by heating to a temperature high enough to give solution of the carbides ( usually 1 050 °C ) followed by cooling at a sufficiently rapid rate to prevent their reformation or by heating at a temperature in the region of 850°C — 900°C for a time sufficient to give homogenization of the chromium in solid solution.
Upsetting test	Test for the detection of surface defects, used to determine the suitability of billets, bars, wire, etc, for hot or cold forging. A specimen is taken, heated or not, and hammered on end until it is reduced by a specified amount.
Passivation	Production of a passive film on the surface of a metal in order to resist corrosion, usually by the production of an oxide film, for example, by treatment with nitric acid.
<b>2.6 Plastics — General</b>	
Plastics materials	( <i>Adj.</i> plastics. ) Wide group of materials which are largely organic and of high molecular weight and which at some stage during manufacture or processing into finished articles can be shaped by flow.
Plastic	( <i>Adj.</i> ) Susceptibility of a material to plastic deformation.
Resin	Member of the group of glassy, amorphous, organic solids, secreted by certain plants and insects, insoluble in water but soluble in many organic solvents and softening under heat; now often referred to as natural resins, for example, colophony.
Synthetic resin	Originally applied to members of a group of synthetic substances which resemble and share some of the properties of natural resins, but now applied in a wider sense to include materials which bear little resemblance to natural resins. Referred generally to the products of step growth polymerization used for example, as surface coatings ( for example alkyd resins, epoxy resins etc ).

<i>Term</i>	<i>Definition</i>
Thermoplastic	( <i>Adj.</i> ) Having the property of softening repeatedly on the repeated application of heat and of hardening when cooled.
Thermoplastic resin	Synthetic resin which will soften when heated and can then be processed by extrusion or moulding.
Thermosetting	( <i>Adj.</i> ) Having the property of hardening and becoming permanently infusible and insoluble.
Thermosetting resin THERMOSET	Synthetic resin which usually, after initially softening, will then harden and become permanently infusible and insoluble when heated.
Crosslinking	Formation of networks of bonds between linear polymers. Crosslinking results in decreased solubility and increased softening temperature and ultimately complete insolubility and infusibility.
Elastomer	( <i>Adj.</i> elastomeric. ) Synthetic rubbers and rubber-like polymers.
Fibre-forming polymer	Polymer from which continuous filaments can be formed and comprising a regular chain structure permitting close alignment of cumulatively strong intermolecular forces.
Crystalline polymer	Polymer in which regularity of structure permits alignment of neighbouring chain molecules into regions of high structural regularity or crystallinity, for example polyethylene is a crystallizing polymer and mechanical and physical properties are very dependent on the amount of crystallinity present.
Composites REINFORCED PLASTICS	Combination of two materials in such a way that the properties are more useful in particular application than those of the individual components. Typical composites containing a strong fibre, ( for example glass, carbon, ceramic ) in a soft matrix ( for example polyester, epoxy or other synthetic resin ).
Inert plastics	(a) Chemical : Non-reactive in a given chemical situation; (b) Medical : Do not react with the tissue in any way after implantation and are themselves unaffected. A theoretical concept used in reference to levels of tissues acceptance or tolerance. The only true test is complete tissue tolerance by the host tissues over the lifetime of the recipient.



<i>Term</i>	<i>Definition</i>
Benign reactivity ( BENIGNLY REACTIVE )	Reaction or interaction with the tissues may occur, but does not have any adverse effect. Such a material may react strongly and play an active part in healing processes.
Nonthrombogenic plastics materials	Plastics materials which provide a non-clotting non-haemolysing blood/plastic interface.
<b>2.7 Plastics — Polymer Chemistry</b>	
Macromolecule	Very large molecule usually comprising recurring structural units.
Manomer	( <i>Adj.</i> monomeric. ) Substance composed of molecules which are capable of reacting with like or unlike molecules to form polymers.
Polymer	Molecules which consist essentially of recurring structural units.
High polymer	Polymer consisting of very large molecules.
Homopolymer	Polymer containing one structural unit only prepared by the polymerization of one monomer.
Copolymer	Polymer containing more than one structural unit prepared by the polymerization of a mixture of two or more monomers, or of a monomer and a polymer of low molecular weight. Copolymers have entirely different properties from those of a mechanical mixture of their homopolymers.
Polymerization	Formation of polymers from simpler molecules.
Polycondensation	Formation of polymers from simpler molecules by their chemical combination with the elimination of simple by-products such as water.
Step growth polymerization	Incorporation of molecules step-by-step into a chain of progressively increasing size. Has largely replaced the term polycondensation.
Addition polymerization	Involves addition to a double bond by a free radical or ionic mechanism to produce polymers in which the molecular weight is the sum of that of the component monomers, and the repeating unit contains the same atoms as the monomer.

<i>Term</i>	<i>Definition</i>
Chain growth polymerization	Rapid formulation of large molecules by radical or ionic mechanism usually from monomers containing ethylenic double bonds.
Initiator	Chemical compound added to monomer to start polymerization is usually by formation of free radicals or ions. Initiators are degraded or incorporated into the polymer ( contrast with catalyst ).
Catalyst	Substance which hastens polymerization or cure when added in relatively small quantities compared to the amounts of primary reactants, and which does not become a component part of the chain.
Accelerator PROMOTOR	Added to polymerization system ( monomer + initiator ) to hasten the process, for example amine used in cold-curing acrylic cement.
Hardener	Chemical compound added to the synthetic resin to bring about crosslinking and network formation, for example amines and polyamides used with epoxy resins.
Inhibitor	Added to ethylenic monomers to prevent polymerization during storage, for example quionones. Act by removal of free radicals.

## **2.8 Plastics — Technology**

Compounding	Incorporation of ingredients to modify specific polymer properties and improve resistance to degradation.
Milling	Process used to soften polymers in which the material is passed between rollers rotating at different speeds usually heated. Additives may be incorporated during the process.
Anti-oxidant	Substances added to plastics materials or rubbers to prevent oxidative degradation during processing or in-service lifetime.
Ultra-violet stabilizer	Substance added to plastics materials to inhibit ultra-violet-induced degradation. Acts either by chemical action on initial products of degradation, or as a selective absorber of radiation.

<i>Term</i>	<i>Definition</i>
Anti-static agent	Material added to rubbers and plastics to make them electrically conductive and thus to reduce hazards arising from build-up of static electricity, for example fine particles of carbon are incorporated into rubbers intended for anaesthetic use. Anti-static properties may deteriorate within a few months of usage.
Plasticizer	Liquid or solid of low vapour pressure at ordinary temperatures used to modify the flow properties of a synthetic resin or of a composition based on a synthetic resin, particularly to increase the flexibility.
Plastisol	Stabilized dispersion of polymer powder in a plasticizing liquid. When heated, the polymer absorbs the liquid and swells to produce a coherent solid mass.
Filler REINFORCING FILLER	Inert solid substance ( for example woodflour, china clay ), added to a synthetic resin to improve mechanical properties.
Stock	Uncured rubber.
Encapsulation POTTING	Covering a device with a monomer or low molecular weight polymer coating, subsequently polymerized or crosslinked.
Casting	Polymerization of a polymer/monomer syrup usually in a mould to provide a solid shaped device or an encapsulation.
Calendering	Preparation of sheet rubber or plastics of predetermined thickness by passing between rollers usually revolving at the same rate. May be used to coat cloth or other backing material.
Dip coating	Coating of substrate with rubber or plastics from solution.
Dipping	Coating of a mould by dipping it into a solution or latex of rubber or plastics. Used for making gloves, balloons, etc.
Mandrel coating	Application of polymer solution to a slowly rotating solid rod or former ( mandrel ) followed by solvent evaporation. Used for making tubing of non-extrudable materials.

<i>Term</i>	<i>Definition</i>
Electrodeposition	Surface coating from a latex by applying an electric charge to the surface to be coated to make it the anode in a suitable cell.
Compression moulding	Heating a granular polymer in a mould while pressure is applied. Used for thermosets.
Injection moulding	Forcing a molten thermoplastic polymer into a mould under pressure used for syringes, etc.
Transfer moulding	Molten polymer is forced by a ram into a hot mould cavity for curing.
Rotational moulding	Formation of hollow articles by adding powdered or plastisol polymer to a mould which is rotated simultaneously in two planes perpendicular to each other while being heated.
Blow moulding	Hollow tube of plastics material is expanded into a mould in which it is enclosed by applications of high pressure air inside the tube.
Mould release agent PARTING AGENT	Lubricant, for example wax, silicone oil, used to coat a mould cavity to prevent the moulded piece from sticking to it and thus to facilitate its removal from the mould.
Lubricant	( In plastics ) used to prevent sticking of thermo-plastic during processing.
Blowing	Process of forming sponge rubber.
Thermoforming VACUUM FORMING	Heated plastics sheet is made to conform to a shape by applying vacuum or pressure.
Extrusion	Process of forcing softened polymer through a die.
Die	Device through which polymer is extruded to give long lengths of uniform cross-section.
Sintering	Granules of polymer are heated under pressure until fusion occurs.
Curing HARDENING	Process of transforming unpolymerized or partly polymerized material to a fully polymerized condition often associated with crosslinking and network formation.

<i>Term</i>	<i>Definition</i>
Pot life	Time during which the mixture is suitable for intended use following addition of catalyst to a polymerizable system.
Dough time	Time required from commencement of mixing to form a coherent dough, for example of acrylic bone cement.
Setting time	Time required from commencement of mixing to the hardened condition at which point the material is no longer mouldable. Not necessarily representative of complete curing.
Spinning	Process of producing high polymeric fibres by the production of filaments from molten polymer or from solution.
Cold drawing	Stretching of filament to produce intermolecular alignment and consequent increase in tensile strength.
Platen	One of a number of steel plates which serve to heat and to transmit pressure to the mould assembly. A platen may be fixed in position relative to the moving table or to the head of the press, or may be floating.
Runner	In injection moulding, the portion of the feed which runs between the gate and the stalk.
Gate	In injection moulding and in transfer moulding: (a) Narrow orifice through which material is injected into a mould cavity from the feed. (b) Moulded material removed from the orifice in the process of extracting the moulding.
Sprue	In injection moulding, that part of the feed immediately adjacent to the nozzle of the injection cylinder and connecting the nozzle to the runner.
Flash	Moulding material which escapes from a mould at a space between its relatively moving parts.
Crazing	Surface cracking.
Dimensional stability	Ability to retain original dimensions.

<i>Term</i>	<i>Definition</i>
Shrinkage	Difference in linear dimensions per unit length between a moulding and the mould cavity in which it was moulded, both the mould and the moulding being at normal room temperature when measured.
Permeability	Ability to permit passage of gases or of small molecules in solution.
Porosity	Ability to permit passage of liquids.

## 2.9 Plastics — Types

Natural rubber HEVEA RUBBER	Natural cis-polyisoprene. Obtained as a latex from the rubber tree <i>Hevea brasiliensis</i> .
Silicone POLYS- ILOXANE SILICONE FLUID SILICONE GEL SILICONE RUBBER POLYDIME- THYL SILOXANE	Family of polymeric materials in which the recurring chemical group contains silicon and oxygen atoms as links in the main chain.

NOTE — Commercial products may be toxic and should not be used in medicine. Medical grade rubbers are prepared with non-toxic vulcanizers.

Polyurethane	Synthetic rubbers typically prepared by reaction of a difunctional alcohol and a di-isocyanate.
Synthetic rubber	Synthetic elastomeric material.
Neoprene POLYCHLORO- PRENE	Synthetic rubber comprising polymers of 2-chloro 1 : 3-butadiene ( chloroprene ).
Polyisoprene ISOPRENE RUBBER	Synthetic rubber comprising synthetic <i>cis</i> -polyisoprene prepared by stereoregular polymerization of isoprene.
Tissue adhesives	Adhesive used primarily as an alternative to sutures for blood vessels and soft tissues.
GRF adhesive	An adhesive based on a combination of gelatin with a resorcinol formaldehyde resin.

<i>Term</i>	<i>Definition</i>
Acrylics	Synthetic polymers of acrylic acid, its esters and other derivatives.
Polymethylmethacrylate	Thermoplastic material composed of polymers of methylmethacrylate.
Acrylic cement BONE CEMENT	Two component room temperature hardening cement. The liquid component is usually methylmethacrylate monomer containing an amine or other activator. The solid component is a fine powder of polymethylmethacrylate copolymer containing a polymerization initiator.
Cyanoacrylate adhesives	Liquid monomers of alkyl <i>o</i> -cyanoacrylate esters characterized by very rapid polymerization initiated by moisture. Sensitive to hydrolytic breakdown, giving formaldehyde and therefore tissue toxic to varying degree.
Vinyl polymers VINYL	Synthetic resin formed by the polymerization of chemical compounds containing the group $\text{CH}_2 = \text{CH}_-$ .
Polyvinyl chloride	Thermoplastic composed of polymers of vinyl chloride.
Polyvinylidene chloride	Thermoplastic composed of polymers of vinylidene chloride ( 1, 1-dichloroethylene )
Polystyrene	Thermoplastic produced by the polymerization of styrene ( vinyl benzene ).
Polyvinyl alcohol	Thermoplastic composed of polymers of the hypothetical vinyl alcohol, soluble in water when the content of hydroxyl groups in the polymer is sufficiently high. Obtained by partial or complete hydrolysis of polyvinyl esters, usually by complete hydrolysis of polyvinyl acetate.
Polyolefins	Prepared by polymerization of olefins, the most common being polyethylene and polypropylene.
Polyethylene	Thermoplastic polymer of ethylene, normally translucent, tough waxy solid which is unaffected by water and by a large range of chemicals.

<i>Term</i>	<i>Definition</i>
Low density polyethylene LDPE	Lower molecular weight polyethylene made by high pressure process in which the chains carry short branches. Closeness of packing is reduced and thus the density. Chains ( crystallinity ) still occur giving toughness and chemical resistance.
High density polyethylene HDPE	High molecular weight polyethylene in which the molecules are sterically very regular, and unbranched, thus permitting close packing.
Ultra high molecular weight polyethylene UHMWPE	Very high molecular weight product preferred for surgical use.
Polypropylene	Thermoplastic polyolefin resin prepared by the controlled polymerization of propylene. Axial orientation of the molecules is an important factor when the material is to be used as hinges, for example in finger joints.
Fluoropolymers	Polymers containing fluorine.
Polytetrafluorethylene PTFE	Obtained from polymerization of tetrafluorethylene in an aqueous medium to give a granular powder or aqueous dispersion.
Polyester	Polymer in which the structural units are linked by ester groupings obtained by condensation of one or more polycarboxylic acid with one or more polyhydric alcohols ( alcohols containing more than one hydroxyl-OH group ) and if desired a minor proportion of a monocarboxylic acid.
Polyester linear	Usually refers to polyethylene terephthalate but may also include propylene and hexylene terephthalate. Linear polymers of this class are represented by strong fibres and monofilaments, and tough high-gloss biaxially orientated unsupported films.
Polyester resin	contain unsaturation ( double bonds ) in the polymer chain from the use of unsaturated carboxylic acid. Dissolved in a polymerizable solvent, usually styrene, and hardens when a polymerization initiator is added. Widely used for glass fibre reinforced plastics.



<i>Term</i>	<i>Definition</i>
Polyamide	Polymer in which the structural units are linked by amide or thio-amide groupings. Many polyamides are fibre forming, generally known as nylons.
Polyethyleneterephthalate	Fibre-forming polyester from ethylene glycol and dimethylterephthalate. Also film forming.
Nylon	Generic name for all synthetic fibre-forming polyamides; they can be formed into monofilaments and yarns characterized by great toughness, strength and elasticity, high melting point and good resistance to water and chemicals.
Polyimide	Polymer containing cyclic structures in the macromolecular chain prepared from reaction between a diamine and an anhydride. Aromatic diamines impart good high temperature properties.
Epoxy resin	Typical resins formed by reaction of epichlorhydrin with diphenylol propane to give a diglycidyl ether. The epoxide groups in these react further usually with amines to give unfusible insoluble products.
Polyacetal	Polymer derived from formaldehyde with general formula $(\text{HO}-\text{CH}_2-\text{O}-\text{CH}_2-\text{O})_n\text{H}$ prepared from reaction of difunctional alcohols with aldehydes.
Polycarbonate	Thermoplastic polymer prepared from reaction between phosgene and diphenylol propane.
Hydrophilic polymer HYDROGEL	Typically crosslinked polymers of hydroxyethylmethacrylate. These materials swell in water to become soft and pliable.
Polyglycolic acid	Linear polymer of glycolic acid. May be extruded into continuous filaments for use as sutures. Hydrolyses in vivo and is completely absorbable.
Carbon fibre	Fibre produced from organic fibre by pyrolysis under controlled conditions.

## 2.10 Bioplasts

Bioplast	Plastics material prepared from high molecular weight materials of biological origin. These materials, after chemical treatment, have temporary use in surgery since they are progressively absorbed. They may or may not produce an undesirable tissue reaction.
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<i>Term</i>	<i>Definition</i>
<b>Fibrin</b>	Protein formed during blood clotting from fibrinogen in the presence of thrombin. Plasticized with water, it may be moulded into shaped articles and cross-linked with formaldehyde.
<b>Collagen</b>	Major protein of skin, connective tissue and bone. It is used for surgical processes when treated with chemical agents.
<b>Bone</b>	Protein-depleted dried bone ( bovine ), non-antigenic, used as bone replacement.
<b>Lyophilized bone</b>	Substantially protein-free dried bone ( bovine ), non-antigenic since residual protein has been denatured.
<b>Alginates</b>	Calcium and sodium salts of alginic acid obtained from seaweed.
<b>Gelatin</b>	Degradation product of collagen following hydrolysis. Obtained from bones and hides by soaking in lime water followed by rigorous purification.
<b>Starch sponge</b>	Prepared from starch by slow freezing followed by freeze drying.
<b>Catgut</b>	Bioplast suture material prepared from the serosa of sheep—a non-vascular collagenous tissue.